ARKIV FÖR FYSIK Band 1 nr 28

Communicated 9 November 1949 by M. Siegbahn and E. Hulthén

On the Ho^{166} disintegration

By Kai Siegbahn and Hilding Slätis

With 3 figures in the text

P. J. Grant and J. M. Hill[1] have recently given a report on some measurements on the radiation from Ho^{166}. A γ-ray of 80.2 ± 0.7 keV was shown to exist and β-spectrometrically an L conversion line corresponding to this γ-energy was found ($\alpha_L \sim 30$ %). Furthermore absorption measurements showed that a very small intensity (about 1.5 %) γ-line of 1.2 ± 0.1 MeV existed. The β-spectrum had an upper limit of 1.88 ± 0.02 MeV.

We have also investigated this isotope recently. In spite of the fact that many of our results agree well with those of Grant et. al. some points in the disintegration may still be discussed.

Thus, we were able to find not only the L conversion line corresponding to $E_\gamma = 80$ keV in the spectrum but also the K and M lines (see Fig. 1).

With a high transmission spectrometer[2] and a Ho sample strongly activated in the Harwell Pile[3] a practically weightless β-source could be used (< 0.1 mg/cm^2). In the curve in Fig. 1 we have not applied any correction for window absorption.

For the K line, which has an energy of only 22.3 keV, the window transmission is about 50 %. The L and M lines will not be absorbed to any measurable amount. Thus, when corrections are applied for absorption, the conversion in the K shell is still much smaller than in the L shell. Such a behaviour may often be an indication of a spin change correlated to the transition, which under certain circumstances may give rise to an isomeric level. Since the daughter nucleus (Er^{166}) contains an even number of neutrons and protons an isomerism here would mean a violation of the Mattauch rule[4], which has been found only in the case of Ge^{72}[5] with some certainty.

In order to investigate this matter more closely coincidence measurements were performed in the spectrometer. Coincidences $C_{\varepsilon\beta}$ between the conversion electrons (K, L and M) focused in the spectrometer and the total β-spectrum, registered with a β-tube behind the sample were investigated. A thin Au foil was inserted between the sample and the β-tube to eliminate coincidences between conversion electrons and X-quanta. The resolving power of

---

[1] P. J. Grant and J. M. Hill, Nature *163*, 524, 1949.

[2] H. Slätis and K. Siegbahn, Ark. f. Fysik 1, 339, 1949.

[3] We express our best gratitude to Dr. Seligman, Harwell, for this irradiation.

[4] J. Mattauch, Zeits. f. Physik *117*, 246, 1941.

[5] J. Bowe, M. Goldhaber, R. Hill, W. Meyerhof and O. Sula, Phys. Rev. *73*, 1219, 1948.

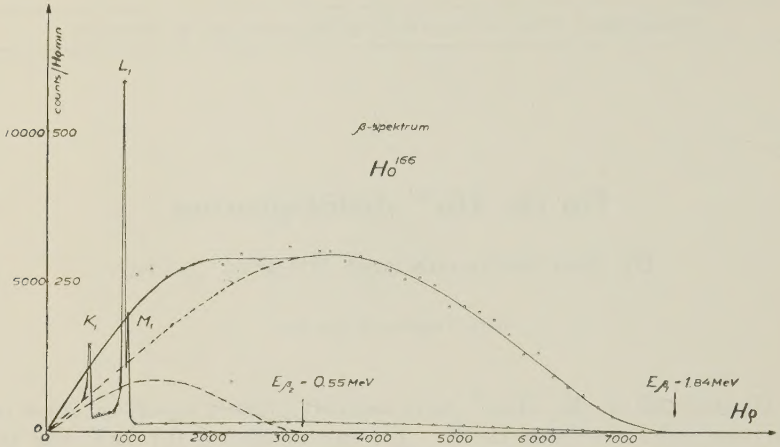

Fig. 1. β-spectrum of Ho^{166} showing the K, L and M lines of the 80 keV γ-lines.

the coincidence amplifier was put at $\sim 3 \times 10^{-7}$ sec. The result was that three well defined $e\beta$-coincidence lines were obtained, showing that the life-time of the excited level is at least less than 3×10^{-7} sec.

If the internal conversion coefficient of the L line is measured by comparing the area under the line with that of the continuous spectrum we obtain the value $\alpha_L = 30$ %. This value is also given by GRANT et. al. after applying a window absorption correction. From the coincidence measurement in the spectrometer α_L can also be determined using the formula $\frac{C_{e\beta}}{N_\beta} = \alpha \cdot \varepsilon_e$, where $C_{e\beta}$ is the number of $e\beta$ coincidences per min., N_β the corrected counting rate in the β counter behind the sample; α the conversion coefficient, and ε_e the efficiency of the spectrometer counter, which is essentially equal to the spectrometer transmission. ε_e can be measured from another β line with known conversion-factor. We used the conversion line of Au^{198} ($E\gamma = 411$ keV) for this purpose ($\alpha_K = 3.2$ %). If α_L for the 80 keV line is measured in this way the value comes out to be smaller than 30 %, i.e. somewhat more than 20 %. The combined errors of all these measurements are of course rather difficult to estimate but there seems to be a small possibility that some of the coincidences are lost because of the life time of the state being in the neighbourhood of 10^{-7} sec., i.e. near the resolving power of the coincidenceamplifier. This matter can only be settled if a resolving power of about 10^{-8} sec. is attained.

It may be of interest in this connection to calculate the approximate theoretical life times, which can be expected[1] assuming different "effective" l-values for the transition. For $l = 3$, i.e. electric octopole or magnetic quadrupole radiation, τ is ~ 0.2 sec. This possibility can be ruled out immediately because of the coincidence results. For $l = 2$, i.e. electric quadrupole or magnetic dipole radiation, τ is $\sim 0.5 \times 10^{-7}$ sec. These estimated values are, however, subject to great uncertainties because of the approximate character of theory. The calculated values refer to the life times for pure γ-emission but since the

---

[1] A. C. HELMHOLZ, Phys. Rev. *60*, 415, 1941.

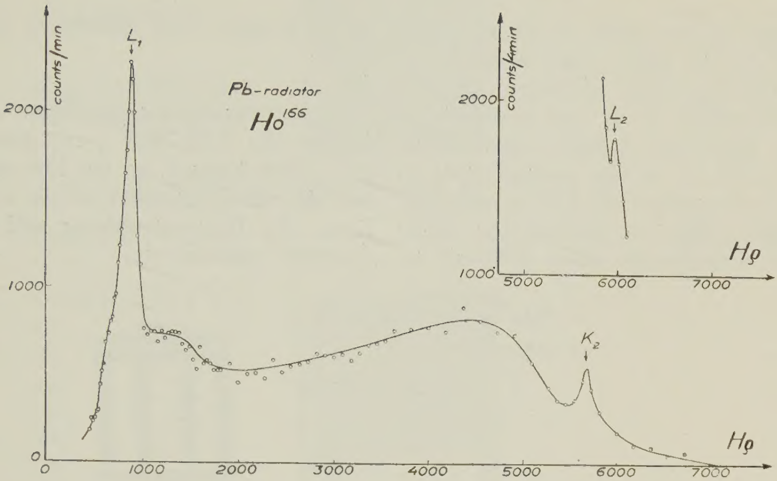

Fig. 2. The secondary electron spectrum of the Ho^{166} γ-radiation using 0.03 mm lead as converter.

total conversion is far from 100 %, the correction due to electron emission is small.

If the influence of screening is taken into account one can, according to HEBB and NELSON[1], compute the L conversion coefficient under different assumptions regarding the l-value. One then finds for $\frac{N_e}{N_q}$, i.e. number of L conversion electron per quantum emitted for electric multipole radiation, in the three cases $l = 1$, $l = 2$, $l = 3$, the following theoretical values: 0.06, 1.9 and 66. The experimental value was ~ 0.4, which is consistent with $l = 2$, i.e. electric quadrupole radiation. It is also consistent with magnetic dipole radiation, which according to formulas by HEBB and NELSON would give $\frac{N_e}{N_q} = 0.10$. The teoretical K/L conversion ratio cannot be computed accurately enough because the γ-ray energy is too near the K binding energy in the present case.

The study of the γ-radiation was also performed with the spectrometer using a very strong sample. The secondary electronspectrum expelled from a 0.03 mm Pb converter is shown in Fig. 2.

The L photo line in lead of the 80 keV γ-ray is very pronounced. The hump in the curve after the line is passed is due to the continuous Bremsstrahlung effect in the converter, which has its approximate maximum in this energy region.[2]

There is still another γ-line, the Compton electron distribution and photolines of which are clearly resolved in Fig. 2. The energy of this γ-line is 1.36 ± 0.01 MeV. This energy obviously corresponds to the γ-energy of 1.2 MeV found by GRANT et. al. by absorption.

A Fermi plot of the β-spectrum showed that this could be resolved into two components, the upper limits of which were 1.84 MeV and 0.55 MeV. The abundance of the softer is about 10 % of the harder. The difference in energy fits well to the hard γ-ray energy.

---

[1] M. HEBB and E. NELSON, Phys. Rev. *58*, 486, 1940.

[2] See K. SIEGBAHN and H. SLÄTIS, Ark. f. Mat., Astr. o. Fysik, 34 A, No 6, 1946.

The disintegration scheme is given in Fig. 3.

Unfortunately it is not possible with our standard $\gamma\gamma$-coincidence arrangement to draw any definite conclusions whether the 1.36 MeV γ-ray goes to the 80 keV level or to the ground state in Er^{166}. This depends on the low efficiency for the unconverted 80 keV γ-radiation and the small intensity of the 1.36 MeV γ-radiation. The $\gamma\gamma$-coincidence effect from the Bremsstrahlung will make a very low coincidence effect difficult to interpret conclusively.

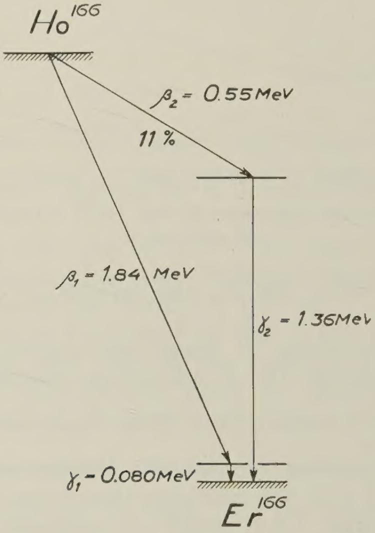

Fig. 3. Disintegration scheme of Ho^{166}.

The intensity of the 1.36 MeV γ-ray is higher than that estimated by GRANT et. al. (1.5 %). A fairly accurate measurement of the γ-intensity could be made using calibrated β- and γ-counters in standard arrangements. By measuring the number of β-particles emitted from the source and correcting the results for the existence of the soft β-lines and for absorption and back scattering (this latter correction was measured accurately as a function of the maximum β-energy for a number of other well known β-emitters) the absolute number of disintegrating atoms could be obtained. The absolute number of 1.36 MeV γ-quanta emitted from the same sample was then measured with a gold γ-counter, the efficiency of which was calibrated as a function of the γ-energy from $\beta\gamma$-coincidence measurements on a number of well known simple disintegration schemes. The influence of the soft 80 keV γ-radiation was measured and corrected for. Two independent measurements performed in this way gave results, which agreed well with that obtained from the less accurate Fermi analysis, i.e. 11 % 1.36 MeV γ-quanta per disintegration.

Tryckt den 18 januari 1950

Uppsala 1950. Almqvist & Wiksells Boktryckeri AB